Analysis of D-STATCOM Control in Low Voltage Distribution System with Wind Power Generation

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***Abstract*- For the last few years, the large scale integration of wind power generation with power system grid is increasing very rapidly. Wind power generation creates some power quality problem such as voltage regulation. So this title deals with the control of D-STATCOM for maintaining voltage profile of the distribution system while employing induction machine based wind power generation. The D-STATCOM consists of three leg IGBT based CC-VSI having DC bus capacitor. A carrier less hysteresis current controller is used for deriving gating pulses for IGBT switches. The control scheme of the D-STATCOM for the grid connected wind power generation system is simulated using MATLAB/Simulink. D-STATCOM is effective for compensating reactive power, Harmonic elimination and improving power quality of distribution system.**

Keywords-D-STATCOM, Wind power generation, Control algorihm-Carrier less hysteresis current control.

1. INTRODUCTION

In recent years, there has been a rapid increase in total installed capacity of wind power generation throughout the world. The global installed capacity of wind power generation is 283MW and in India it has gone to 20MW. This increasing growth of wind power generation affects the operation of the existing power system network. Because the integration of wind power generation to the distribution system presents the problem of voltage regulation and reactive power compensation.

A common type of joint turbine consists of a squirt cage induction generator, so it always uses reactive power, which is not required for the distribution system. This type of generator that generates the voltage after the voltage collapse slowed down and the voltage fluctuates when the wind turbine is connected to the distribution system. Due to the wind speed change, wind turbine produces energy fluctuations. It is therefore important to know how a group of air turbines connected to the network system distribution network can affect the power quality. Energy fluctuations are the most important component in the air turbine to determine the effect of air turbine connecting the grid on energy quality. As IEC STD 61400-21 [6], grid provides measurements and measurement of air turbines connected to it. This power quality problem can be solved using custom power devices.

The role of custom power devices [1-2] plays an important role in improving the power quality of the distribution system. Adaptive power equipment for power quality improvement. Compatible electrical devices, such as D-STATCOM, DVR and UPQC, generally work in the distribution system. Custom power concept based on the use of the electric electronics controller in the distribution system to improve the power quality of the distribution system
The meaning of the custom power is that customer receives specified power quality from utility or service provider.

II D-STATCOM (Distribution Static Compensator)

Basic Concept of The D-Statcom

STATCOM working on delivery or loads is called D-STATCOM. D-STATCOM consists of a VSC, a DC bus capacitor, a compressor transformer connected to shunt with the AC system. At the level of broadcasting, STATCOM only regulates reactive power compensation and provides voltage support. The D-STATCOM behaves as a function filter when working on a scale or load. D-STATCOM is a GTO / IGBT based VSI that is connected to the power system by Powerful Colorling. Generally GTOs are used for a higher power application such as STATCOM to the level of transmission. IGBTs are used for the medium for small power application and are used in D-STATCOM [6].

The D-STATCOM voltage source inverter (VSI) or current source inverter (CSI) acts as a capacitor or inductor with reactive power storage. Generally, electric voltage source inverters are widely used because of their low volumes, low heat and low cost capacitor less expensive capacitor compared to the indirect used in CSI for the same power rating. D-STATCOM (CC-DS) and D-STATCOM, such as voltage-controlled D-SATCOM (VC-DS), can use different control methods. Of these, CC-VSI is commonly used to improve power quality in D-STATCOM. There are two subdivisions in this category [5]

A) **Voltage control D-STATCOM**: Active and reactive power flow control by inverter using D-STATCOM as a voltage source.

B**) Current control D-STATCOM**: The most commonly used method is to control energy by controlling its active and reactive flow through D-STATCOM.

PRINCIPLE OF OPERATION

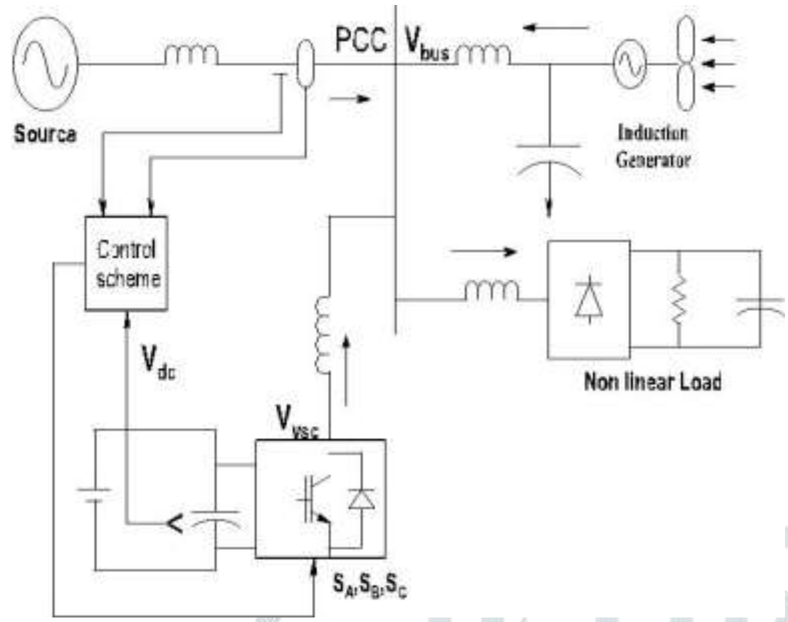

Figure 1: Schematic diagram of D-STATCOM

The operating principal of D-STATCOM depends on the

reactive current generation so,

I=(Vbus-Vvsc)/X

Where,

Vbus=system voltage

Vvsc=output voltage of the VSC

X=circuit reactance

The current system produced by D-STATCOM adjusts voltage sag by adjusting the voltage on system errors. When the system is placed in quadrature with voltage when introduced by D-STATCOM, the voltage correction can be achieved without entering any active power to the system. The effect of D-STATCOM in replacing the voltage sag is mainly based on the assertion value (Zth = R + JX) and the error level at the load bus [8].

D-STATCOM can minimize voltage variation and restrict the reactive power crash with the system. It provides capacitive and reactive current to the system at PCC (the location of the common combination).

There are two types of operating modes of D-STATCOM

1) Inductive mode

2) capacitive mode

In D-STATCOM's inductive mode, Vbus is in Vvsc and Vbus> VvsC absorbs reactive power from the D-STATCOM system. In capacitive mode of operation of D-STATCOM, Vbus <Vvsc distributes reactive power to D-STATCOM systems. The above analysis includes both Vbus and Vvsc, but in fact they have a small phase difference, so it is possible to convert real electricity flow into the system, supplying losses of transformer reactors and losses in the investor.

The D-STATCOM system also provides a real power switch between D-STATCOM. If the Vvsc Vbus is guided by an angle, then the actual energy flow to the system. If Vvsc is a VBus with an angle, then the actual electrical current from the system to D-STATCOM. Active and Reactive power transferred by the D-STATCOM is given as,

P=[(Vbus*Vvsc)/X] sinä

Q=(Vbus^2/X)-[(Vbus*Vvsc)/X] cosä

The capacitor in D-STATCOM is used to maintain DC voltage investor. The output of the investor is in proportion to the DC voltage of the voltage capacitor, which is proportional to the power stored in the capacitor. Capacitor size can be chosen based on its physical size, price and performance of D-STATCOM.

Although the D-STATCOM function exceeds its high or low voltage limit, the D-STATCOM system has the ability to control the voltage by properly maintaining the voltage converter output voltage as a current source. So at low voltage or high voltage limit, D-STATCOM provides higher reactive power compensation than SVC.

III. WIND TURBINE POWER GENERATION BASIC CONCEPT

Wind turbine is a type of energy source delivered. There are various DERs such as air turbine, anoprocating engine, combustion turbine, fuel cell, photovoltaic system. The wind turbine changes the dynamics of the wind into useful energy, which is used by mechanical work, producing electrical energy using water pumping or generator. It consists of small roof turbines that produce less than 100 kW to a large commercial air turbine in the lower MW range. The energy available from the air is given

$$P=\acute{} A ñ V^3$$

Where, ñ=Density of the air

=1.225 kg/m³ at sea level
A=Capture area in m²
V=Wind speed in m/sec.

There are various types of wind turbines, mainly a. Horizontal axis wind turbine (HAWT) b. Vertical axis wind turbine (VAWT)

In HAWTs, its blades rotating on an axis parallel to the ground and axis of blades rotation parallel to the wind flow.Also rotor shaft and electrical generator placed at the top of the tower. A gear box is also provided in the nacelle of the turbine, which turns the slow variation of the blades into a quicker rotation of the blades i.e. stepping up the speed of the generator. There are some constant speed turbines, but more energy can be generated by the variable speed turbines, which uses a solid state power converter for the purpose of integration with the system. A protective circuit can also be equipped with turbine to avoid damage at very high wind speed.

In VAWTs, blades rotating on axis perpendicular to the ground. A rotor shaft arranged vertically, because of this arrangement, transmission and generator can be maintained at ground level which allows the easy maintenance and light weight, low cost tower. But main disadvantage is that relatively low rotational speed with the consequential higher torque and hence higher cost of the drive train.
Grid Connection: This is required after the production of energy, which is broadcast and distributed to consumers. The wind generating energy that provides food directly to local loads is called the discrete wind power system. A grid-connected air power system is called a system connected to the grid if the air power is supplied.

IV.CONTROL STRATEGIES

To control the voltage source converter and DC link voltage, a variety of control methods [7] are used to control D-STATCOM.

PHASE SHIFT CONTROL
The simplest method of maintaining continuous voltage load terminals. This technology provides voltage angle control and produces a step shift between the VSC and the production voltage of the system voltage. The voltage reference in the PCC is comparable to the voltage, which gives the error code, and provides the PL controller to produce a dimension to maintain the voltage flaw to zero. This angle then plays the PWM generator, which modulates the synovial voltage signal by an angle and produces pulses for IGBT switches.
This control method is very strong, and requires only voltage measurement. But this technology has the following losses,
• It does not have a self-support DC bus and it requires a special DC source to charge the capacitor during operation of D-STATCOM and maintain its voltage.
• There is no provision for hormone suppression.

CARRIER BASED PWM CONTROL
The PVM of the frequency carrier based synthesis is used to generate switch pulses for VSC's IGBTs switches. The current measurements of instant voltage and supply system and load in this control method are measured. The abc-dq transformation of this method occurs, so the current components produce id and iq, which are compensated by controlling id and iq. ID indication flow now derived from the PI control of DC terminal voltage in relation to DC voltage. As well as the IC Reference current can be obtained by PI control of VC's AC terminal voltage.

Then PI control of these reference streams compared variance id and iq respectively, which generates vd and vq respectively, and then publishes PWM pulse generator to produce convertible pulses for IGBT VSC.

There are many glitches in this control manner,

- Very low hormonal suppression is achieved, which requires additional filters to reduce hormonics.
- Response time is high because of using four PI controllers.
- PLL is required for the synchronization with the fundamental frequency and also produce error when supply voltage is distorted.

CARRIER LESS HYSTERESIS CONTROL

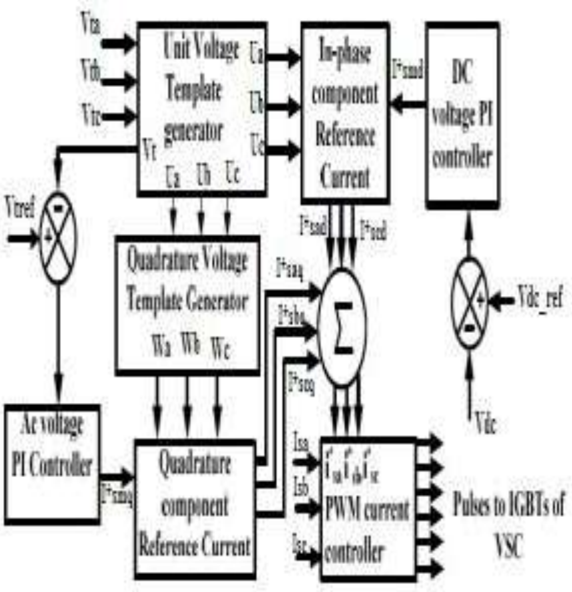

Figure 2: schematic diagram for carrier less hysteresis control of D-STATCOM

This control technology is very versatile and widely used for voltage control, power factor correction, minimizing labor, and load balancing. Figure PI controller-based carrier shows low hysteresis controller. They can be measured in phase unit vectors (U, UB and UC) by dividing the voltages through the Vt and Quadrature Unit Vectors (WA, WB, WC) at PC V (VA, VB, VC) Step Unit Vectors.

To control the voltage during normal calling (PCC), a voltage (VT) is absorbed from the PCC and is compared to reference voltage (Vtref) and its error is processed in the voltage PI controller and the PI controller outputs as I* smq, reactive current derived by D-STATCOM Spread out. Quadrature component of the current current (I * saq, I * sbq, I*scq) can be obtained by multiplying I*smq with Quadrature Unit Vector (WA, WB, WC).

To provide voltage control at DC bus, the PI control of DC bus voltage handles the DC voltage indicator and output I * smd, which shows the spread of the active power component of the reference source current. Phase Unit Vector (U, UB, UC) I am * smd by reference to the source of reference source current (I * sad, I * sbd, I * scd). Now the reference source current (I * sa, I * sb, I * sc) can be obtained by adding the relevant phase and quadrature components. Then PWM compares Reference Source Currents (I * sa, I * sb, I * sc) with Source Current Currents (ISA, ISB, ISC) to produce exchange pulses for IGBT's current controller D-STATCOM.

The hysteresis controller places a hysteresis band ±h around the calculated reference source current, for (Isa-I*sa) > +h, then pulses are generated for lower level switches and for (Isa-I*sa) < -h, then pulses are generated for upper level switches of the VSC.

Algorithm of carrier less hysteresis control

The magnitude of three phase voltage at the PCC is calculated as,

$$Vt=\sqrt{(2/3)\,(Va^2+Vb^2+Vc^2)}$$

The unit in-phase vectors Ua , Ub , Uc are derived as

Ua=Va/Vt;

Ub=Vb/Vt;

Uc=Vc/Vt;

Unit vectors in quadrature (Wa , Wb , Wc), are derived from

the in-phase vectors (Ua , Ub , Uc), using following transformation

$$Wa= -Ub/\sqrt{3}+Uc/\sqrt{3};$$

Wb= √3Ua/2+(Ub-Uc)/2 √3;

Wc= - √3Ua/2+(Ub-Uc)/2 √3;

Quadrature component of the reference source current:

The voltage at PCC is sensed and compare with the reference voltage, and error signal obtained as,

Ver(n)=Vtref-Vt(n)

Where,
Vtref=Amplitude of reference voltage at PCC

Vt(n)= Amplitude of the three phase ac voltage at PCC at the nth instant

Quadrature component of the reference source current I*smq(n) can be obtained from the output of the PI controller for maintaining ac terminal voltage constant at nth instant, and is expressed as,

I*smq(n)=I*smq(n-1)+Kpa{Ver(n)-Ver(n-1)}+KiaVer(n)

Where,

I*smq(n)=amplitude of reactive power component of the source current

Kpa and Kia=proportional and integral gain constant of PI controller

The quadrature component of reference source current can estimated as,

I*saq=I*smq Wa;

I*sbq=I*smq Wb;

I*scq=I*smq Wc;

In-Phase component of reference source current:

The dc link voltage is sensed and compare with the reference dc voltage, and error signal obtained as,

Vdcer(n)=Vdcref-Vdc(n)

Where,
Vdcref=reference dc voltage
Vdc(n)=sensed DC link voltage of the D-STATCOM

The output of the PI controller for maintaining the dc bus voltage of the D-STATCOM at the nth sampling instant is expressed as,

I*smd(n)=I*smd(n-1)+Kpd{Vdcer(n)-Vdcer(n-1)}+Kid Vdcer(n)

Where,I*smd(n)=amplitude of the active power component of the source current

Kpd & Kid=proportional and integral gain constants of the dc bus PI voltage controller

In-Phase component of the reference source currents are computed as,

I*sad=I*smd Ua;

I*sbd=I*smd Ub;

I*scd=I*smd Uc;

Total reference source currents:

It is the sum of the quadrature and in-phase component of reference source currents,

I*sa = I*saq + I*sad;

I*sb = I*sbq + I*sbd;

I*sc = I*scq + I*scd;

PWM current controller:

These reference source currents (I*sa,I*sb,I*sc) are compared with the sensed source currents (Isa,Isb,Isc), and current errors are computed as,

Isaerr=I*sa-Isa;

Isberr=I*sb-Isb;

Iscerr=I*sc-Isc;

V. CONCLUSION

A comprehensive review of the D-STATCOM controller has been carried out in this paper to focus on the solution of power quality problems. A review has been presented in this paper about the methods for improving power quality aspect of the distribution system connected with wind power generation.

REFERENCES

[1] Panierge, SK. Biswas, Bhim Singh, "Review of Static Compensation of Autonomous System", International Journal of Power Electronics and Drive system (IJPEDS), vol. 2, No. 1, ISSN: 2088-8694

[2] N.G. Hingorani, "Overview of Custom Power Application", Hingorani Power Electronics, 26480 Weston drive, Los Altos Hills, CA 94022
T.Devaraju, Dr. V.C. Vera Reddy, d. M. Vijaya Kumar,

[3] "The role of dedicated energy devices in promoting energy quality: a review," International Journal of Engineering and Technology Science, vol.2 (8), 2010, 3628-3634

[4] M.K. Mishra, Arindam Ghosh, Avinash Joshi, "Operation of a DSTATCOM in Voltage Control mode", IEEE Transactions in Power delivery, vol.18, No.1, January-2003

[5] M.A. Eldery, E.F. El Sadany, Magdy M.A. Salama, "DSTATCOM Effect on the Adjustable Speed Drive Stability Limits, "IEEE Transaction on Power Delivery, vol.22, No.2, April 2007

[6] MA Ahmedabrahimi, Amir, "Improving the Mistake"
Behavior of wind farms facing wind speed changes
Using STATCOM ", IEEE Symposium in Industrial Electronics and Application (ISIEA 2010), October 3, 2010,

[7] V.Kumbha, N.Sumanthi, "Improving Power Quality
Distribution lines using DSTATCOM are under different
Download Condition ", International Modern Journal
EngineeringResearch (IJMER), VOL.2, Issue.5, sep-
oct.2012, pp-3451-3457

[8] Mujtaba Tahani, Imam Rahbari, Samira Memarian,
"Simulation and Technical Comparison of the Wind Turbine Power Control System", The Renewable World

[9] Energy Conference, Sweden, 8-13 May 2011.
A.Ananda Kumar, G.Ganeshwar Kumar "Power
Compensation at the Distribuion level using the VSC system
STATCOM ", International Journal of Engineering
Research & Technology (IJERT) ISSN: 2278-0181, vol.1, Issue.5, July-2012

[10] S.M. Shinde, K.D. Patel, WZ. Gandhare, "Dynamic Compensation of Reactive Power for Integration of WindPower in a Weak Distribution Network", International Conference on Control, automation, communication and energy conservation-2009,

4th-6th June 2009.

BOOKS

[11] R. Mohan Mathur, R.K.Varma, "Theater, based FACTS Controllers for Electrical Transmission System", Chapter: 10, page No. 413-461, A John Wiley and Sons, INC.

[12] Narayan J. Hingorani, Laszlo Gyuji, "understanding FACTS Concepts and FACTS Systems Technology, "chapter 5, page No.135-208, ISBN: 0-7803-3455-8, IEEE order No.PC5713